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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

SUPPLEMENTARY FREE-SPINNING-TUNNEL INVESTIGATION OF A $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH EXTERNAL STORES INSTALLED

TED NO. NACA DE 2393

By Jack H. Wilson

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Langley Field, Va.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
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SUMMARY

A supplementary investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effect of external stores and lateral center-of-gravity displacement upon the spin and spin-recovery characteristics of a $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane. The effects of control settings and movement upon the erect spin and recovery characteristics of the model were determined with wing-tip tanks installed and with an experimental aerodynamic shape installed in combination with a tank on the opposite wing tip with the center of gravity alternately on center laterally and displaced laterally by simulating a variable amount of fuel in the tank. Tests were also made with the aerodynamic shape alone installed with the center of gravity displaced laterally.

With wing-tip tanks installed and the center of gravity of the model on center laterally, the recovery characteristics were satisfactory. When, however, the center of gravity was on center laterally with the experimental aerodynamic shape and one partially full tip tank installed, the recovery characteristics of the model were unsatisfactory. When the center of gravity was displaced laterally with tip tanks installed or with the experimental aerodynamic shape and one tank installed on the opposite wing tip, the recovery characteristics of the model were unsatisfactory only in the direction opposite to the lateral center-of-gravity displacement (i.e. right wing heavy, left spin recovery unsatisfactory

[redacted]

or left wing heavy, right spin recovery unsatisfactory). Recoveries were satisfactory in either direction, however, when the experimental aerodynamic shape alone was installed.

INTRODUCTION

In accordance with a request of the Bureau of Aeronautics, Navy Department, supplementary spin tests were performed in the Langley 20-foot free-spinning tunnel to determine the effect of external stores and lateral center-of-gravity displacement upon the spin and spin-recovery characteristics of a $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane. Tests were performed previously in the Langley 20-foot free-spinning tunnel on the $\frac{1}{20}$-scale model with the center of gravity on center laterally with and without tip tanks installed. These tests are reported in reference 1. These tests were undertaken to investigate the possible cause of a crash of a McDonnell F2H-3 airplane in an asymmetric lateral mass condition during tests of the aileron power-boost system. The airplane and corresponding model tests were conducted with one wing-tip tank full (170 gallons of fuel, full scale) and the other wing-tip tank empty. Model tests were also conducted with both wing-tip tanks only half full (85 gallons, full scale). In addition, the present investigation included tests to determine the effect of installing an experimental aerodynamic shape weighing either 1730 or 3300 pounds, full scale, under one wing with or without an empty, partially full, or full wing-tip tank installed on the opposite wing.

SYMBOLS

b — wing span, ft

S — wing area, sq ft

$\bar{c}$ — mean aerodynamic chord, ft

$x/\bar{c}$ — ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord

$y/\bar{c}$ — ratio of distance of lateral center of gravity from plane of symmetry of model to mean aerodynamic chord

$z/\bar{c}$ — ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord, positive when center of gravity is below reference line

m — mass of airplane, slugs

I_X, I_Y, I_Z — moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2

$\frac{I_X - I_Y}{mb^2}$ — inertia yawing-moment parameter

$\frac{I_Y - I_Z}{mb^2}$ — inertia rolling-moment parameter

$\frac{I_Z - I_X}{mb^2}$ — inertia pitching-moment parameter

ρ — air density, slug/cu ft

μ — relative density of airplane, $m/\rho Sb$

α — angle between fuselage reference line and vertical (approx. equal to absolute value of angle of attack at plane of symmetry), deg

ϕ — angle between span axis and horizontal, deg

V — full-scale true rate of descent, ft/sec

Ω — full-scale angular velocity about spin axis, rps

MODEL AND TESTING TECHNIQUE

The $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane used for the tests of reference 1 was also used for the present investigation. The wing-tip tanks and experimental aerodynamic shape were independently ballasted to maintain dynamic similarity at a spin altitude of 15,000 feet (ρ = 0.001496 slug per cubic foot). A three-view drawing of the model with wing-tip tanks installed is shown in figure 1. The experimental aerodynamic shape as investigated on the model is shown as figure 2. (On the airplane this experimental aerodynamic shape is installed under one wing 54 inches, full scale, from the plane of symmetry and a wing-tip tank is installed on the opposite wing tip with enough fuel in the tip tank to bring the center of gravity on center laterally.) The dimensional characteristics of the model as tested are given in table I. The tail-damping power factor was computed by the method given in reference 2.

The technique used for obtaining and converting data was the same as that used for the original F2H-3 model tests. (See ref. 1.)

The precision of the measurements made and of the data presented is believed to be approximately the same as that listed in reference 1.

TEST CONDITIONS

Tests of the model were conducted with flaps and landing gear retracted and canopy closed for the conditions listed subsequently. For each condition investigated only those stores indicated were installed on the model:

A. Center of gravity on center laterally

(1) Tip tanks half full (85 gallons in each tank, full scale)

(2) Heavy experimental aerodynamic shape (3300 pounds, full scale) installed under one wing and 82 gallons of fuel simulated in the tip tank on the opposite wing

B. Center of gravity displaced laterally

(1) One tip tank full (170 gallons, full scale) and the opposite tank empty

(2) Light experimental aerodynamic shape (1730 pounds, full scale) installed under one wing and 170 gallons of fuel simulated in the tip tank on the opposite wing

(3) Heavy experimental aerodynamic shape (3300 pounds, full scale) installed under one wing and an empty tip tank on the opposite wing

(4) Heavy experimental aerodynamic shape (3300 pounds, full scale) installed under one wing

The mass characteristics and inertia parameters for these loadings and for other loadings possible on the airplane with external stores installed are shown in table II and plotted in figure 3. As discussed in reference 3, figure 3 has been used in the past as an aid in predicting the relative effectiveness of the controls on the recovery characteristics of models with the center of gravity on center laterally.

The model in the clean condition was ballasted for the take-off loading in accordance with the mass information reported in reference 1. The wing-tip tanks and experimental aerodynamic shape were independently ballasted so that with the addition of the appropriate external stores the proper mass distribution of the model was obtained.

For convenience, the light (1730 pounds, full scale) condition of the experimental aerodynamic shape will hereinafter be referred to as the experimental aerodynamic shape 1 and the heavy (3300 pounds, full scale) condition of the experimental aerodynamic shape will hereinafter be referred to as the experimental aerodynamic shape 2.

The maximum control deflections used for the current tests, the same as those used in reference 1, were:

Rudder, deg	20 right, 20 left
Elevator, deg	15 up, 15 down
Ailerons, deg	20 up, 20 down

RESULTS AND DISCUSSION

The results of the spin tests are presented in charts 1 to 6.

As is customary in spin-tunnel testing, model spins were made to both right and left in order to evaluate the effects of any inadvertent aerodynamic asymmetry inherent in the model. In those instances where significant differences in results for right and left spins were obtainable without a measurable difference in dimensional characteristics of the model, it was felt that the corresponding airplane might exhibit a range of recoveries; therefore, the range of recoveries obtained on the model are presented. The model data are given in terms of the full-scale airplane at a test altitude of 15,000 feet.

Wing-Tip Tanks Installed

85 gallons of fuel in each wing-tip tank.- The results of spin tests of the model simulating 85 gallons of fuel in each wing-tip tank (loading point 2 in table II and fig. 3) are presented in chart 1. The model spins for all control configurations were very steep with the rate of descent of

the model exceeding the maximum airspeed attainable in the tunnel. The results of the model tests indicated that the recovery characteristics of the F2H-3 airplane for this loading condition will be satisfactory by rudder reversal alone. It is recommended, however, that normal recovery technique (full rudder reversal followed approx. 1/2 turn later by movement of the elevator down), similar to that recommended in reference 1, be used for recovery from spins of the airplane.

<u>170 gallons of fuel in one wing-tip tank and the other wing-tip tank empty</u>.- The results of tests of the model simulating 170 gallons of fuel in one tip tank and with the other tank empty (loading point 3 in table II and fig. 3) are presented in chart 2. When the full tip tank was on the inboard wing (right wing heavy in a right spin or left wing heavy in a left spin) the model spins for all control configurations were very steep with the rate of descent of the model exceeding the maximum vertical velocity of the tunnel. The results of the model tests indicate satisfactory recovery characteristics for the F2H-3 airplane with 170 gallons of fuel in the inboard wing-tip tank and with the outboard wing-tip tank empty, provided both rudder and elevator are reversed for recovery regardless of the position of the ailerons. When, however, the full tip tank was on the outboard wing (left wing heavy in a right spin or right wing heavy in a left spin), results of the tests presented in chart 2 indicate a steep spin with rapid recoveries for the aileron-full-with, elevator-full-up spin and either flat spins with poor recoveries or steep spins with rapid recoveries for the normal control configuration (ailerons neutral, elevator full up) and for the ailerons-full-against, elevator-full-up spin. It is felt that the results presented in chart 2 indicate the range of recoveries possible when the airplane is spun with outboard wing heavy. On the basis of these results, the recovery characteristics of the F2H-3 airplane are considered unsatisfactory for the condition with 170 gallons of fuel in the outboard fuel tank and the inboard fuel tank empty. It thus appears that the crash of the McDonnell F2H-3 test airplane for this loading condition could possibly have resulted from failure to recover from a spin.

Experimental Aerodynamic Shape Installed

<u>Experimental aerodynamic shape 1 installed on one wing and 170 gallons of fuel in the wing-tip tank on the opposite wing</u>.- The results of tests obtained with the experimental aerodynamic shape 1 (1730 pounds, full scale) installed on one wing and 170 gallons of fuel simulated in the tip tank on the opposite wing as illustrated in figure 2 (loading point 4 in table II and fig. 3) are presented in chart 3. For this configuration the center of gravity was displaced laterally toward the full wing-tip tank. When the full tip tank was on the inboard wing (center of gravity displaced laterally to the right in a right spin), the spins were

very steep with the rate of descent of the model exceeding the maximum vertical velocity of the tunnel and recoveries by reversal of rudder and elevator were rapid. When the full tip tank was on the outboard wing (center of gravity displaced laterally to the left in a right spin), however, poor recoveries were indicated for spins with the elevators full up when the ailerons were set to neutral or against the spin, but setting the ailerons to full with the spin had a favorable effect on recoveries. The recovery characteristics of the airplane are thus considered unsatisfactory when the center of gravity is displaced laterally towards the outboard wing (left wing heavy in a right spin).

Experimental aerodynamic shape 2 installed on one wing and an empty wing-tip tank installed on the opposite wing.- The results of tests obtained with the experimental aerodynamic shape 2 (3300 pounds, full scale) installed on one wing and an empty tip tank installed on the opposite wing (loading point 5 in table II and fig. 3) are presented in chart 4. For this loading condition, the center of gravity was displaced laterally toward the experimental aerodynamic shape. Results for this loading condition were similar to those obtained for the previous condition in that unsatisfactory recoveries were obtained when the center of gravity was displaced laterally towards the outboard wing, whereas satisfactory recoveries were obtained when the center of gravity was displaced towards the inboard wing.

Experimental aerodynamic shape 1 or 2 installed on one wing and sufficient fuel in the wing-tip tank on the opposite wing to bring the center of gravity on center laterally.- Test results with the experimental aerodynamic shape 2 (3300 pounds, full scale) installed on one wing and 82 gallons of fuel simulated in the wing-tip tank on the opposite wing to bring the center of gravity on center laterally (loading point 6 in table II and fig. 3) are presented in chart 5. Results obtained on the model when spun with the experimental aerodynamic shape 2 on either the inboard or outboard wing were similar, and therefore only one set of test results is presented in the chart. Although satisfactory recoveries were obtained for the normal control configuration, a flat spin with a $3\frac{1}{2}$-turn recovery was indicated as possible for the criterion spin (elevator full up, ailerons $\frac{1}{3}$ against). Inasmuch as a $3\frac{1}{2}$-turn recovery from the criterion spin on the model is considered an indication of unsatisfactory recovery characteristics for the corresponding airplane, the recovery characteristics of the F2H-3 airplane for this loading condition are thus considered unsatisfactory.

Analysis indicates that, if experimental aerodynamic shape 1 is installed and balanced laterally by placing sufficient fuel (27 gallons, full scale) in the tip tank on the opposite wing to bring the center of gravity on center laterally (loading point 7 in table II and fig. 3), the spin-recovery characteristics of the airplane may also be unsatisfactory.

Experimental aerodynamic shape 1 or 2 installed on one wing and no wing-tip tank installed.- The results of tests obtained with the experimental aerodynamic shape 2 (3300 pounds, full scale) installed on one wing and no tip tank installed on opposite wing (loading point 8 in table II and fig. 3) are presented in chart 6. With the experimental aerodynamic shape installed either on the inboard wing or the outboard wing, the results were similar with steep spins and rapid recoveries generally being obtained. Inasmuch as the model results indicate satisfactory recoveries for the criterion spin (elevator full up, ailerons 1/3 against) even when the center of gravity was displaced laterally towards the outboard wing, the recovery characteristics of the airplane should be satisfactory for this loading condition. Analysis indicates that similar results should be obtained with experimental aerodynamic shape 1 installed in place of aerodynamic shape 2 (loading point 9 in table II and fig. 3).

These results indicate that when the experimental aerodynamic shape alone is installed on the model on the outboard wing, an aerodynamic antispin yawing moment is probably produced which provides for satisfactory recoveries despite the fact that the center of gravity is displaced laterally toward the outboard wing. (It has been shown previously that displacing the center of gravity toward the outboard wing had an adverse effect on recoveries.) Also, it appears that placing a wing-tip tank on the inboard wing produces an aerodynamic effect which tends to promote the spin. However, with the experimental aerodynamic shape installed on the outboard wing and the center of gravity displaced laterally outboard, unsatisfactory recoveries were obtained when a tip tank was installed on the inboard wing; whereas, satisfactory recoveries were obtained when the tip tank was removed from the inboard wing.

Recommended procedure for recovery attempts.- It is recommended that no intentional spins be made on the F2H-3 airplane when the center of gravity is displaced laterally. In the event a spin is inadvertently entered, however, the ailerons should be moved to full with the spin during the incipient phase of the spin and this control movement should be followed immediately by normal manipulation of the controls (full rudder reversal followed approx. 1/2 turn later by movement of the elevator down). If recovery does not appear imminent for any loading condition with external stores installed, it is recommended that the external stores be jettisoned and another attempt at recovery be made by normal use of controls.

CONCLUSIONS

Based upon the results of supplementary tests of a $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane, the following conclusions and recommendations regarding the spin and recovery characteristics of the airplane with external stores installed for a spin-test altitude of 15,000 feet are made:

1. With wing-tip tanks installed, recoveries will be satisfactory by normal use of the controls (full reversal of the rudder followed 1/2 turn later by movement of the elevator down) if the center of gravity is on center laterally or if the center of gravity is displaced laterally inboard. When the center of gravity is displaced laterally outboard (left wing heavy in a right spin), unsatisfactory recoveries will probably be obtained. It appears that the crash of the McDonnell F2H-3 airplane when flown with one tip tank full (170 gallons) and the other tank empty could possibly have resulted from failure to recover from a spin.

2. With the experimental aerodynamic shape and a tip tank installed, recoveries will be satisfactory by normal use of controls when the center of gravity is displaced laterally inboard. With the center of gravity on center laterally or displaced laterally outboard, recoveries may be unsatisfactory.

3. Recoveries will be satisfactory by normal use of the controls when the experimental aerodynamic shape alone is installed.

4. If recovery does not appear imminent after normal manipulation of the controls for any combination of the external stores installed on the airplane, it is recommended that the external stores be jettisoned and another attempt at recovery be made.

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1. Wilson, Jack H.: Free-Spinning Tunnel Investigation of a $\frac{1}{20}$-Scale Model of the McDonnell F2H-3 Airplane. NACA RM SL51G17, Bur. Aero., 1951.

2. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

3. Neihouse, Anshal I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery From a Spin. NACA ARR, Aug. 1942.

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

MCDONNELL F2H-3 AIRPLANE

Over-all length, ft	48.04
Wing:	
Span, ft	41.7
Area, sq ft	294.0
Section, wing-fold	NACA 65_1-212
Incidence, deg	-0.5
Aspect ratio	5.9
Dihedral, deg	3.0
Mean aerodynamic chord, in.	88.4
Leading edge of $\bar{c}$ rearward of leading edge of root chord, in.	0
Ailerons:	
Mean chord, rearward of hinge line, ft	1.24
Span, percent b/2	32.8
Horizontal tail surfaces:	
Total area, sq ft	70.1
Span, ft	17.8
Elevator area, rearward hinge line, sq ft	18.7
Distance from $0.256\bar{c}$ to elevator hinge line, ft	24.0
Dihedral, deg	10.0
Vertical tail surfaces:	
Total area, sq ft	39.9
Rudder area rearward hinge line, sq ft	9.6
Distance from $0.256\bar{c}$ to rudder hinge line, ft	22.2
Tail-damping power factor	0.000145
Tail-damping ratio	0.0096
Side-area moment factor	0.6

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS POSSIBLE FOR THE MCDONNELL F2H-3 AIRPLANE WITH EXTERNAL STORES INSTALLED

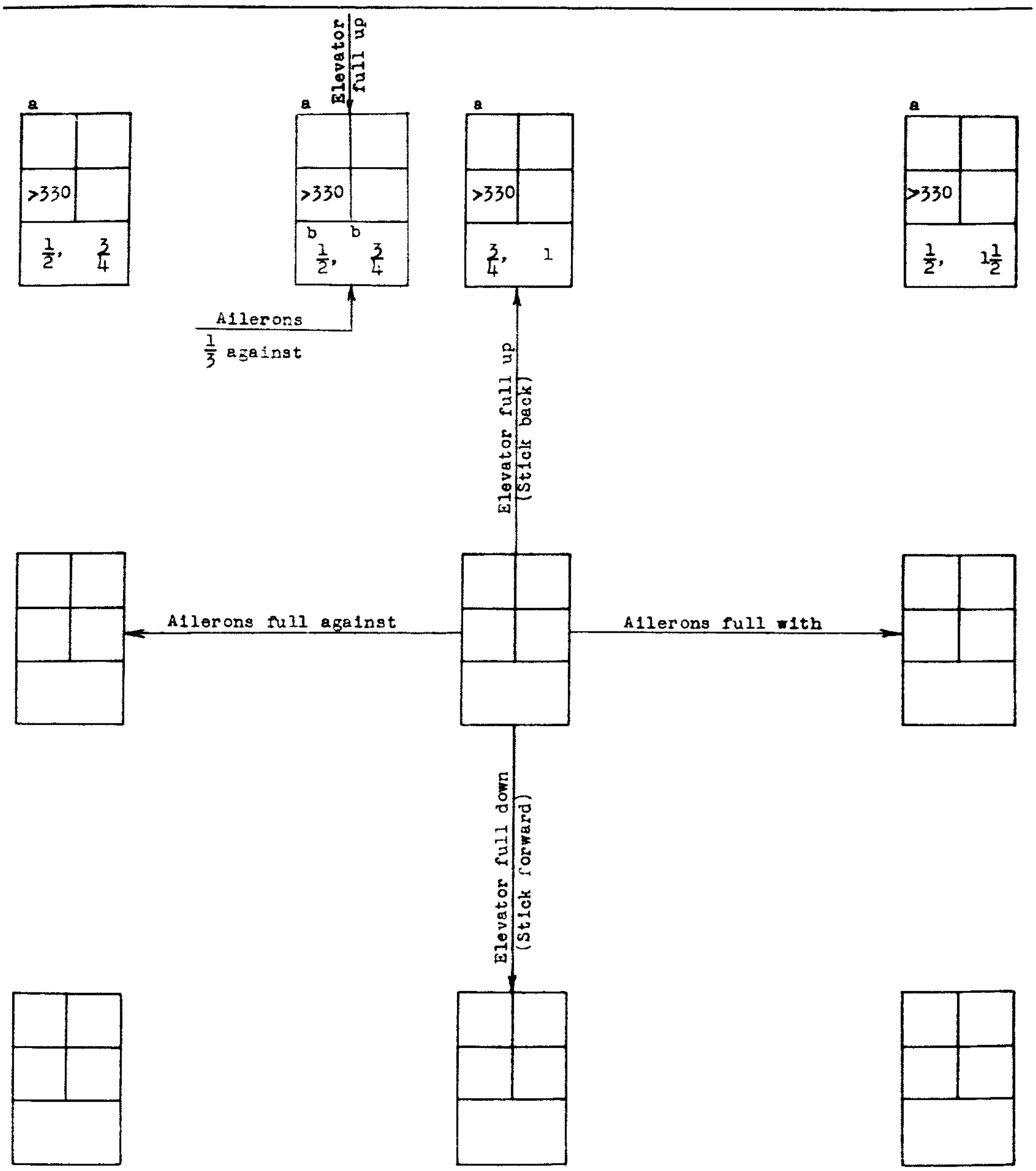
[Moments of inertia are about center of gravity]

Number	Loading [a]	Weight (lb)	μ		Center-of-gravity location			Moments of inertia (slug-ft^2)			Mass parameters		
			Sea level	15,000 ft	$x/\bar{c}$	[b] $y/\bar{c}$	$z/\bar{c}$	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1	Take-off loading No external stores installed	20,762	22.1	35.2	0.257	0	0.175	15,145	41,677	54,616	-237×10^{-4}	-116×10^{-4}	353×10^{-4}
2	85 gallons of fuel in each tip tank	22,186	23.7	37.6	0.256	0	0.198	35,852	41,686	75,253	-49	-281	330
3	One tank full (170 gallons) and one tank empty	22,186	23.7	37.6	0.256	[c] 0.136	0.198	35,172	41,685	74,628	-54	-275	329
4	Experimental aerodynamic shape No. 1 and a full tip tank (170 gallons)	23,718	25.4	40.2	0.235	-0.107	0.207	34,354	42,669	73,288	-65	-239	304
5	Experimental aerodynamic shape No. 2 and an empty tip tank	24,261	25.8	41.0	0.217	0.060	0.232	21,133	43,200	59,887	-169	-128	297
6	Experimental aerodynamic shape No. 2 and 82 gallons of fuel in one tip tank	24,750	26.4	41.9	0.218	0	0.232	28,404	43,209	67,158	-111	-179	290
7	Experimental aerodynamic shape No. 1 and 27 gallons of fuel in one tip tank	22,860	24.4	38.7	0.235	0	0.207	22,301	42,666	61,240	-165	-151	316
8	Experimental aerodynamic shape No. 2 and no tip tank	24,062	25.7	40.7	0.217	0.084	0.233	18,078	43,191	56,845	-193	-105	298
9	Experimental aerodynamic shape No. 1 and no tip tank	22,497	24.0	38.1	0.234	0.048	0.207	16,927	42,665	55,866	-212	-109	321
10	Experimental aerodynamic shape No. 1 and an empty tip tank	22,697	24.2	38.5	0.235	0.021	0.207	19,908	42,667	58,842	-186	-132	318
11	Experimental aerodynamic shape No. 2 and a full tip tank (170 gallons)	25,283	27.0	42.7	0.218	-0.062	0.231	36,004	43,208	74,758	-53	-232	285

[a] Basic loading is take-off loading.
[b] Unless otherwise indicated a positive value indicates that the center of gravity is displaced laterally towards the experimental aerodynamic shape.
[c] Center of gravity displaced laterally towards the full tip tank.

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH 85 GALLONS OF FUEL IN EACH WING-TIP TANK

[Loading point 2 in table II and figure 3; recovery by full rapid rudder reversal except as noted (recovery attempted from, and steady-spin data presented for, rudder-full-with spins)]



[a]Recovery attempted before model in final, steeper attitude.
[b]Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.

Model values converted to corresponding full-scale values
U inner wing up
D inner wing down

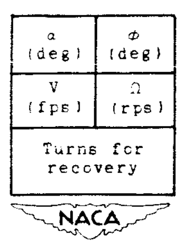
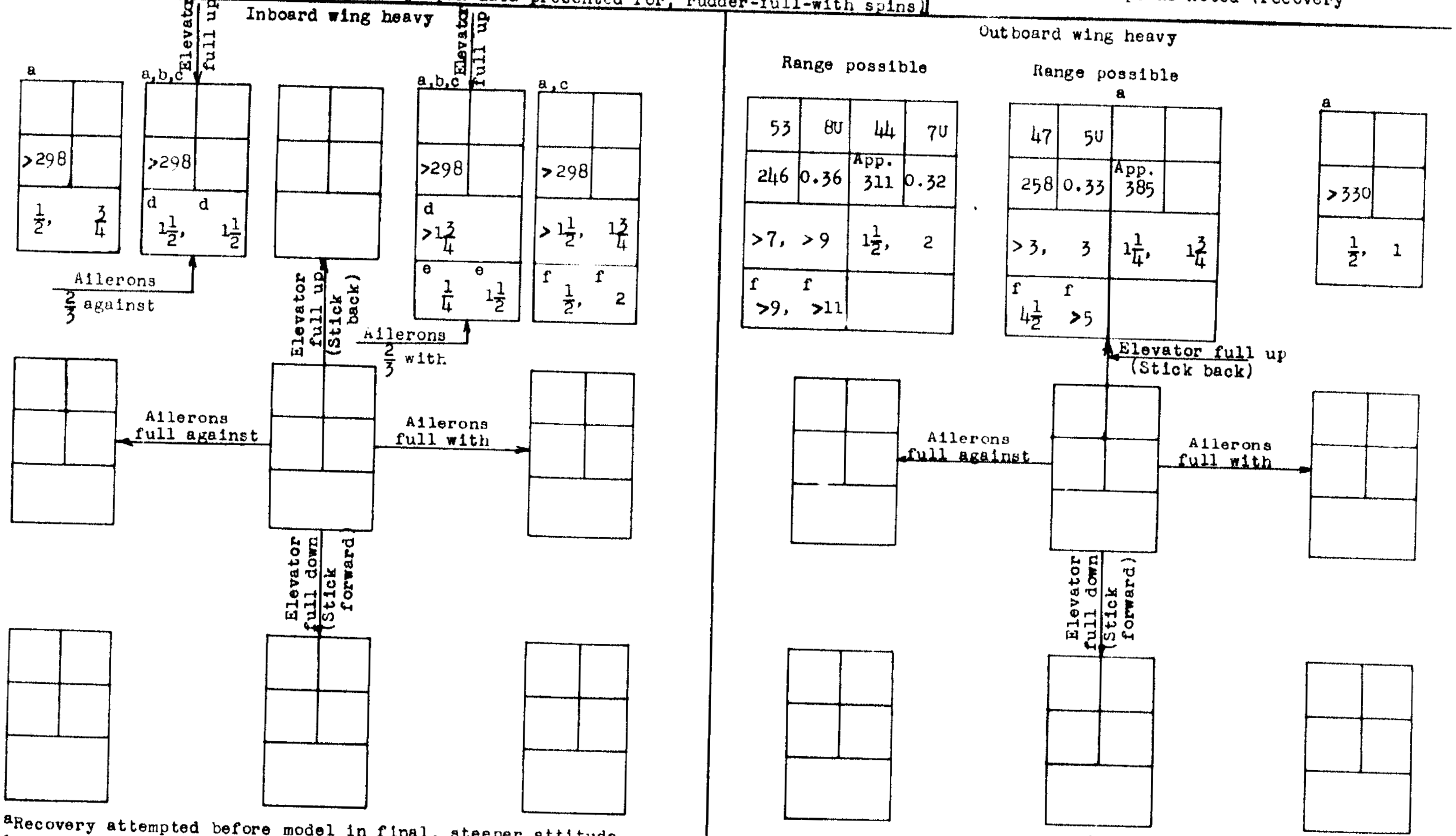
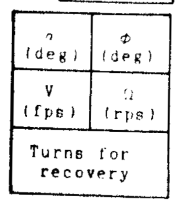


CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH 170 GALLONS OF FUEL IN ONE WING-TIP TANK AND THE OTHER WING-TIP TANK EMPTY

[Loading point 3 in table II and figure 3; recovery attempted by full rapid rudder reversal except as noted (recovery attempted from and steady-spin data presented for, rudder-full-with spins)]



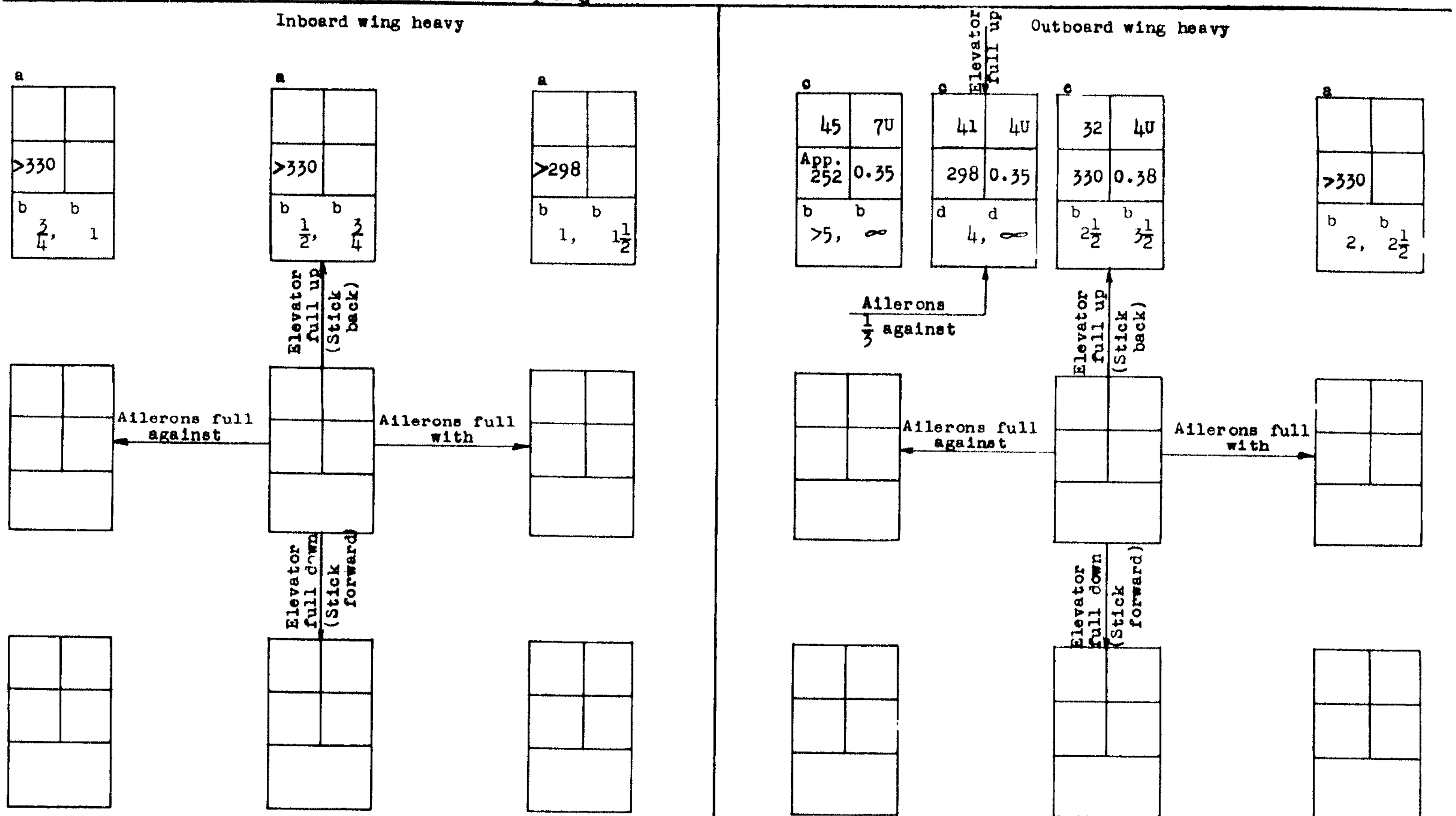


Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a] Recovery attempted before model in final, steeper attitude.
[b] Wandering spin.
[c] Whipping spin.
[d] Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.
[e] Recovery attempted by simultaneous reversal of rudder from full with to $\frac{2}{3}$ against the spin and elevators from full up to $\frac{2}{3}$ down.
[f] Recovery attempted by simultaneous reversal of rudder from full with to full against the spin and elevators from full up to full down.

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH EXPERIMENTAL AERODYNAMIC SHAPE 1 INSTALLED ON ONE WING AND 170 GALLONS OF FUEL IN THE WING-TIP TANK ON THE OPPOSITE WING

[Loading point 4 in table II and figure 3; recovery attempted as indicated (recovery attempted from and steady-spin data presented for rudder-full-with spins)]



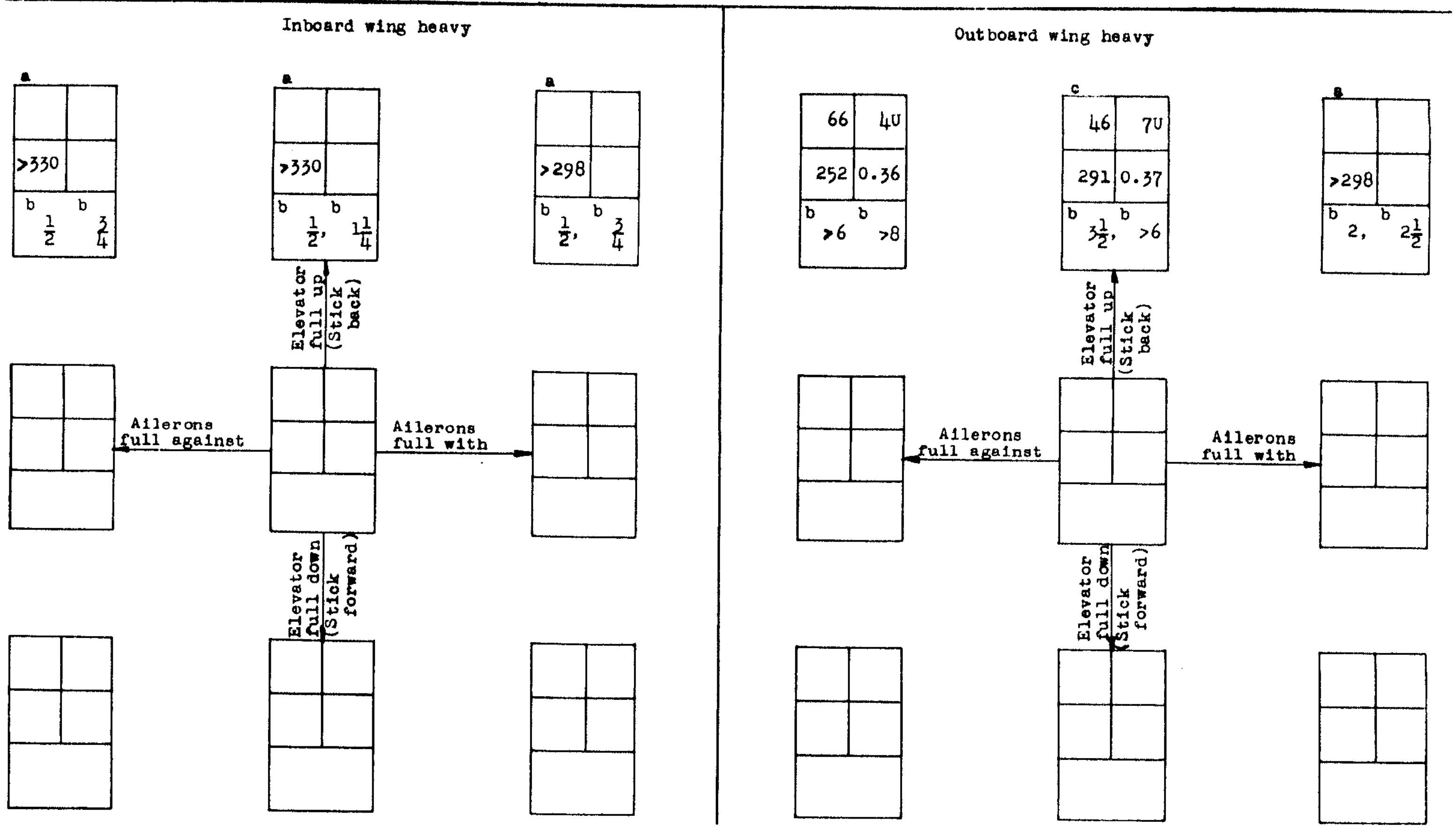
α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

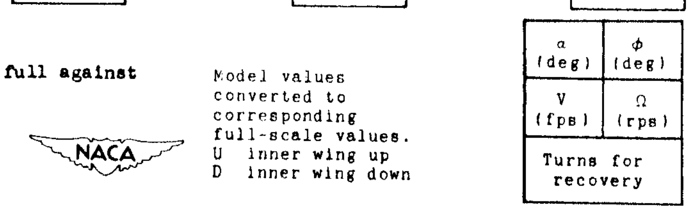
Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a]Recovery attempted before model in final, steeper attitude.
[b]Recovery attempted by simultaneous full reversal of the rudder and elevator.
[c]Wandering spin.
[d]Recovery attempted by simultaneous reversal of rudder from full with to $\frac{2}{3}$ against the spin and elevator from full up to $\frac{2}{3}$ down.

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH EXPERIMENTAL AERODYNAMIC SHAPE 2 INSTALLED ON ONE WING AND AN EMPTY WING-TIP TANK INSTALLED ON THE OPPOSITE WING

[Loading point 5 in table II and figure 3; recovery attempted as indicated (recovery attempted from, and steady-spin data presented for, rudder-full-with spins)]

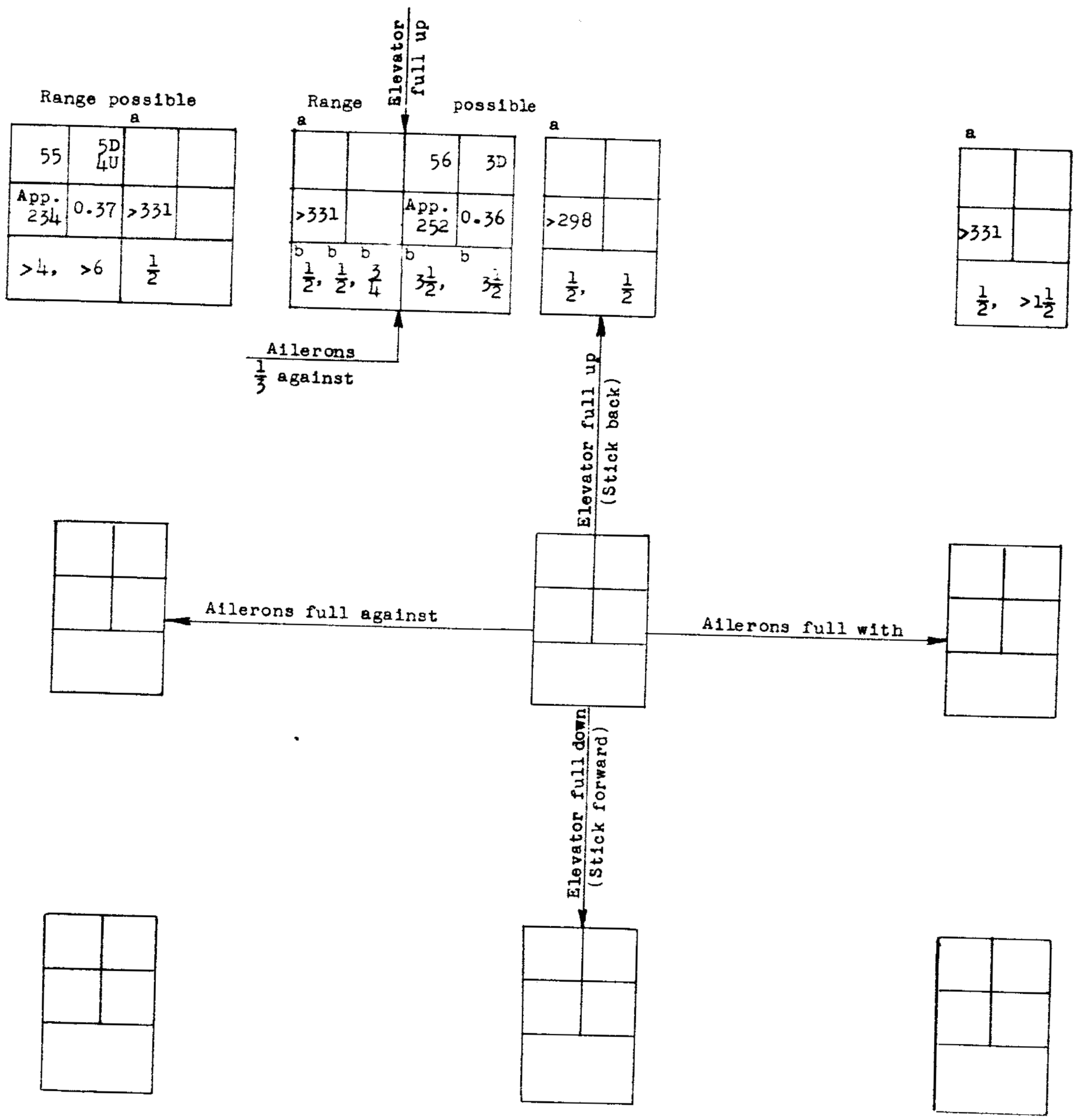




[a]Recovery attempted before model in final, steeper attitude.
[b]Recovery attempted by simultaneous reversal of rudder from full with to full against the spin and elevator from full up to full down.
[c]Wandering spin.

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH EXPERIMENTAL AERODYNAMIC SHAPE 2 INSTALLED ON ONE WING AND SUFFICIENT FUEL (82 GALLONS, FULL SCALE) IN THE WING-TIP TANK ON THE OPPOSITE WING TO BRING THE CENTER OF GRAVITY LATERALLY ON CENTER

[Loading point 6 in table II and figure 3; recovery attempted by full rapid rudder reversal except as noted (recovery attempted from and steady-spin data presented for, rudder-full-with spins)]



[a]Recovery attempted before model in final, steeper attitude.

[b]Recovery attempted by reversal of rudder from full with to $\frac{2}{3}$ against the spin.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

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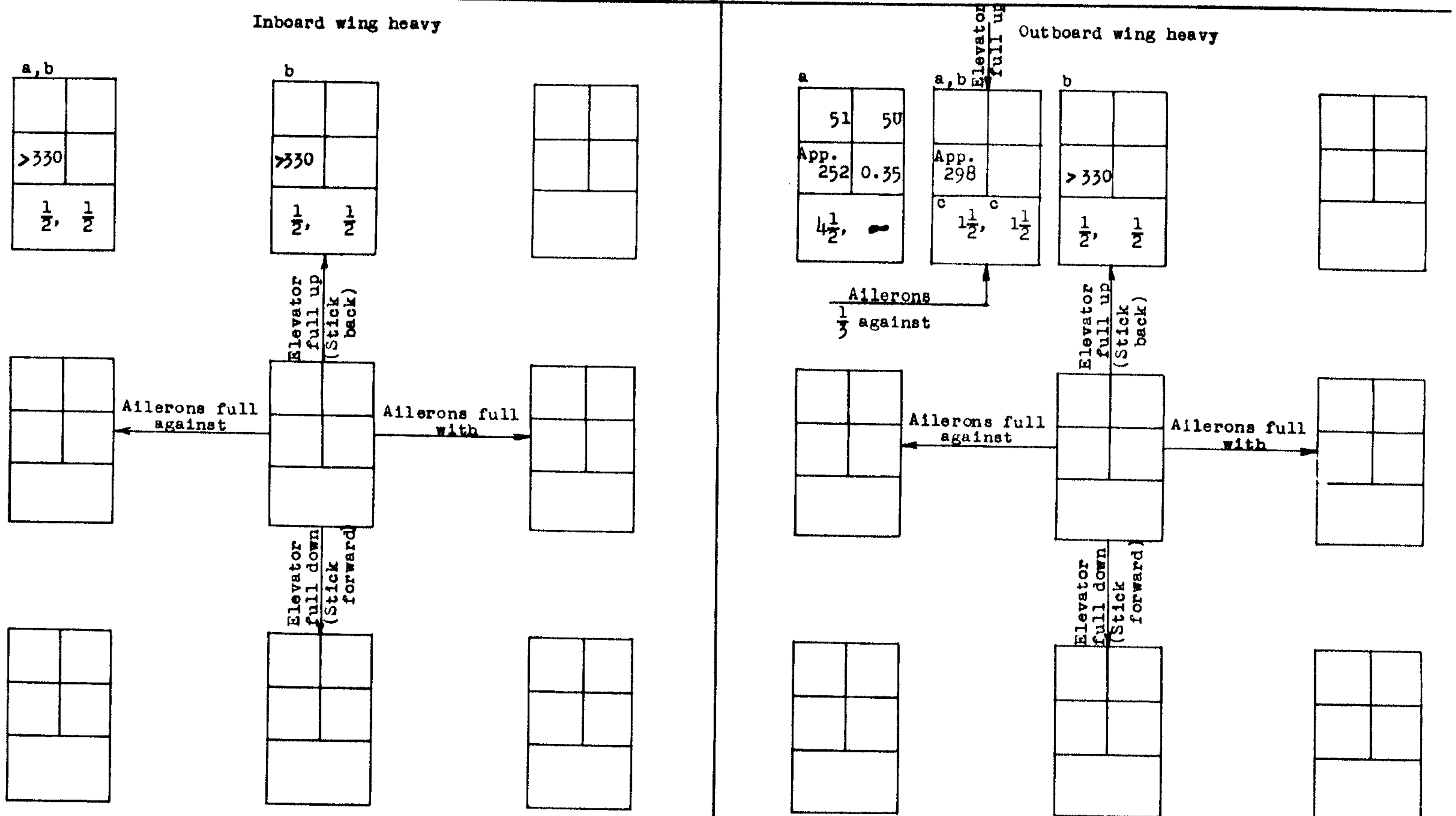
CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF THE $\frac{1}{20}$-SCALE MODEL OF THE MCDONNELL F2H-3 AIRPLANE WITH THE EXPERIMENTAL SHAPE 2 INSTALLED ON ONE WING AND NO WING-TIP TANK INSTALLED

[Loading point 8 in table II and figure 3; recovery attempted by full rapid rudder reversal except as noted (recovery attempted from and steady-spin data presented for, rudder-full-with spins)]



[a]Wandering spin.
[b]Recovery attempted before model in final, steeper attitude.
[c]Recovery attempted by reversal of rudder from full with the spin to $\frac{2}{3}$ against the spin.

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

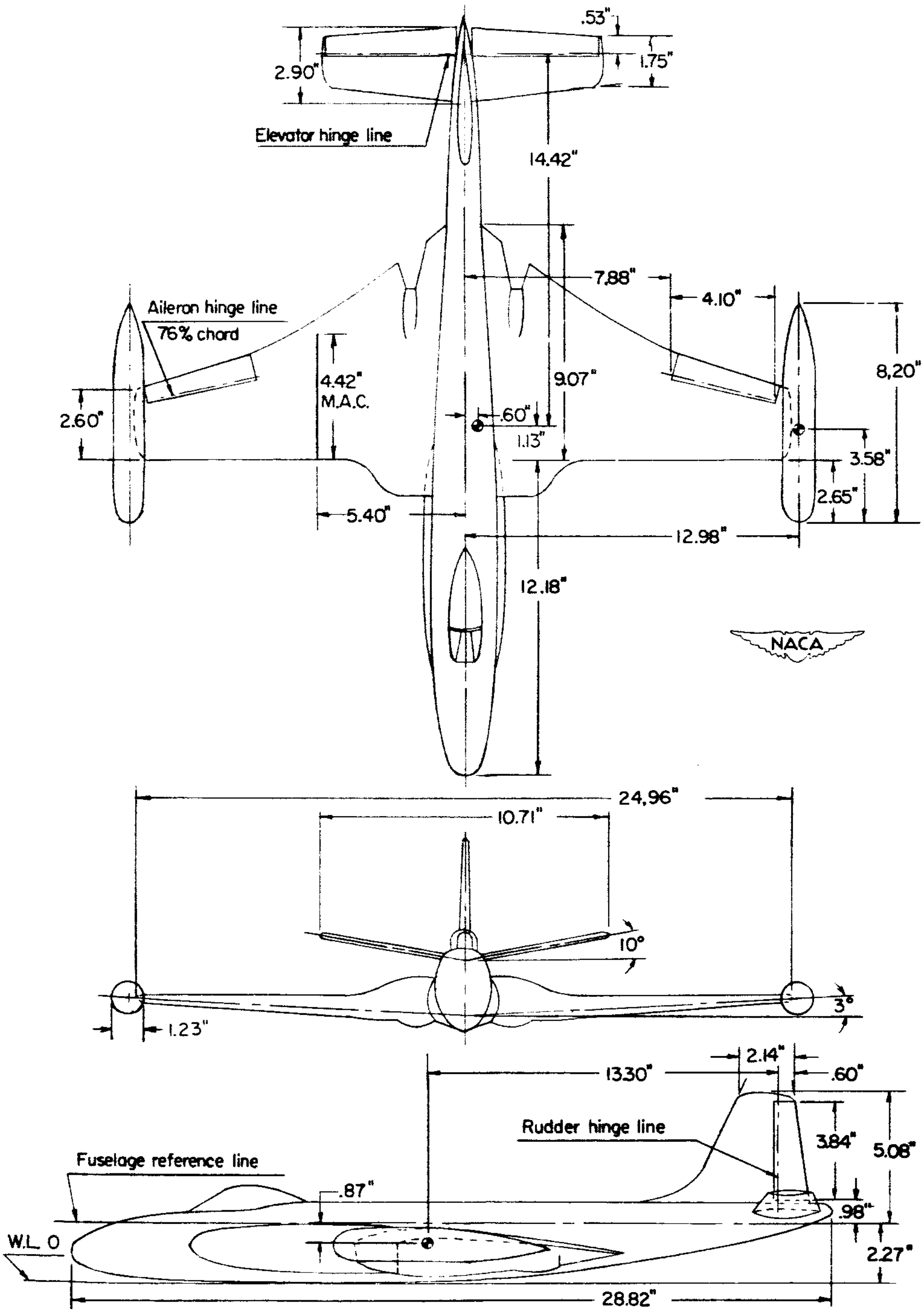


Figure 1.- Three-view drawing of the $\frac{1}{20}$-scale model of the McDonnell F2H-3 airplane as tested in the Langley 20-foot free-spinning tunnel. Center of gravity is indicated for the take-off loading plus a full (170 gallons, full scale) left wing-tip tank and an empty right wing-tip tank.

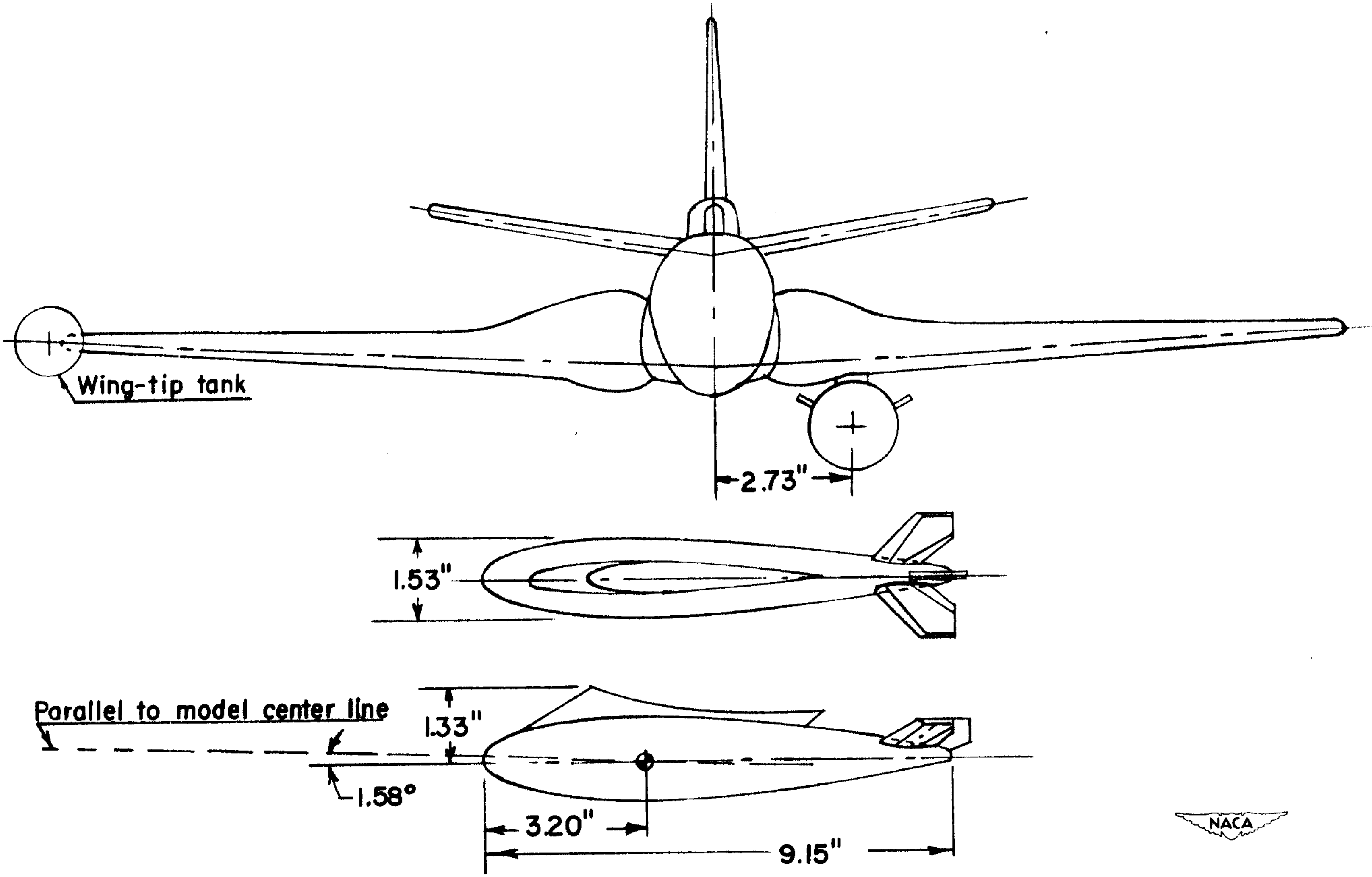


Figure 2.- The installation and shape of the experimental aerodynamic shape as investigated on the model.

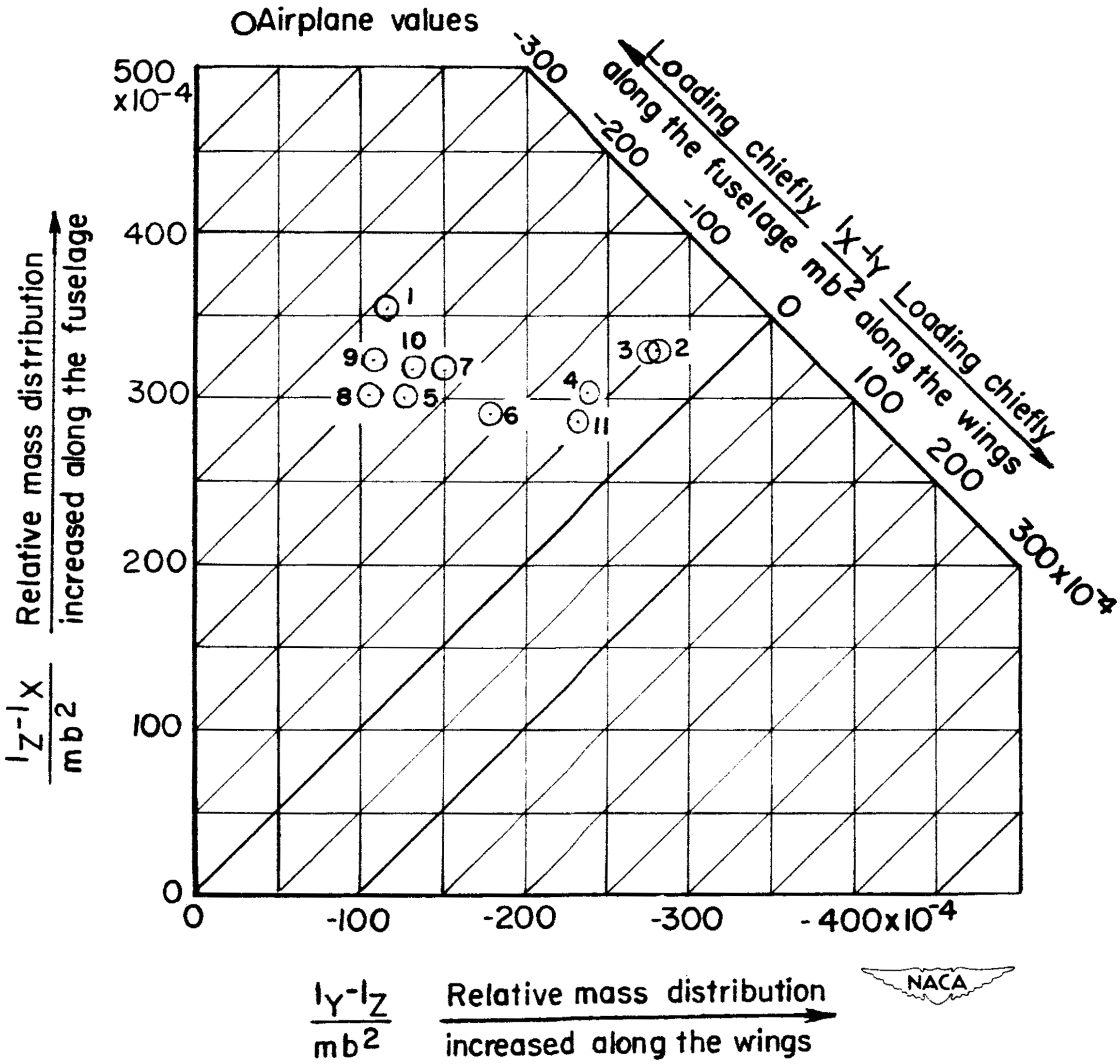


Figure 3.- Mass parameters for loadings possible on the McDonnell F2H-3 airplane. Points are for loadings listed in table II.